EMISSION CHARACTERIZATION FROM NITROGEN DOPED DIAMOND WITH RESPECT TO ENERGY CONVERSION

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Abstract

Vacuum thermionic energy converters utilize electron emissive materials as a key component in the transformation of thermal into electrical energy.[1] A thermionic cell is comprised of an emitter held at an elevated temperature separated from a cooler collector by a vacuum gap. Energy can now be transferred from the hot to the cold side by thermionic excitation of charge carriers and an exterior electrical path allows the electrons to do work when they return to the emitter. Conventional energy converters based on flat metal surfaces were performance limited due to high operating temperatures exceeding 1500K and space charge effects. Diamond films have been subject of numerous emissivity studies where field emission was the dominant form of emission characterization.[2] Several studies on thermionic emission from nitrogen doped diamond films describe emission in terms of donor/defect states as well as the negative electron affinity (NEA) surface characteristic with emission commencing at temperatures below 1000K.[3] In fact, the observed uniformity in the emission can be attributed to the NEA characteristic which is not typical for other carbon based emitters that exhibit locally confined emission. Basically, local uniformity in thermionic emission as observed for flat metal surfaces can be described by the Richardson-Dushman equation where the emission current density follows

$$J = AT^2 e^{-\varphi/k_B T}, \qquad [1]$$

with

$$A = \frac{emk_B^2}{2\pi^2\hbar^3}. \qquad [2]$$

Two parameters dominate the emission described by this relation, the work function, φ, of the material and Richardson's constant, A. The emission barrier, i.e. the temperature at which emission commences is then determined by the work function, φ, of the emitter. While A for a metal has been described theoretically with the result a collection of fundamental constants an experimental evaluation also identifies the contribution of surface characteristics to the solution. By measuring thermionic emission from nitrogen doped diamond films with respect to the Richardson-Dushman equation an evaluation of emission critical parameters can be performed. As shown in Figure 1, emission can be detected at temperatures as low as 900K with a strong increase in emission with emitter temperature. The observed emission behavior, i.e. a stronger increase in emission with temperature than predicted by Richardson is due to a temperature dependent work function which decreases with increasing temperature. In the observed temperature range an average work function for this material of ~2.4eV and a Richardson constant of 120A/cm^{2}K^2 can be obtained with the work function the most critical fitting parameter. By increasing the electric field between emitter and collector, an increase in the emission current is observed which is due to a diminished effective work function.

FIGURES

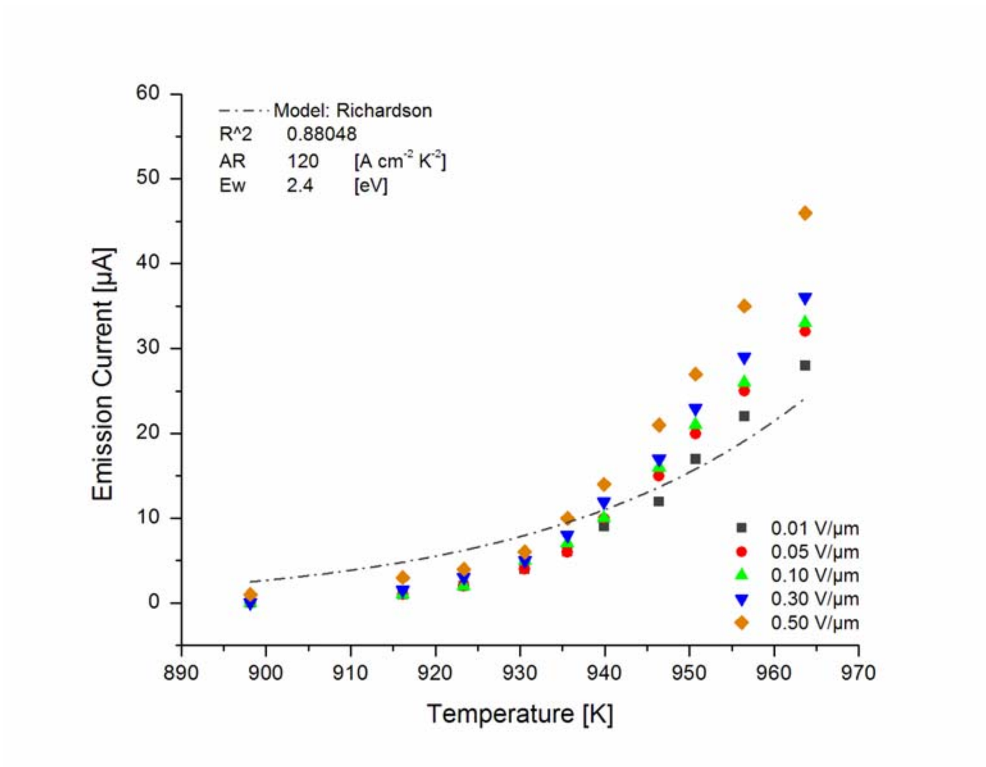

Figure 1. Thermionic electron emission from a nitrogen doped diamond film as a function of temperature and applied electric field. The dotted curve shows a fit to the Richardson-Dushman equation.

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